ESD-TR-68-153

THIRD QUARTERLY TECHNICAL REPORT-2430-3

1 October to 30 December 1967

January 1968

DEPUTY FOR SURVEILLANCE AND CONTROL SYSTEMS
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

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(Prepared under Contract No. AF 19(628)-67-C-0308 by The Ohio State University, ElectroScience Laboratory, Department of Electrical Engineering, 1320 Kinnear Road, Columbus, Ohio.)

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FOREWORD

The report, OSURF report number 2430-3, was prepared by The Ohio State University ElectroScience Laboratory, Department of Electrical Engineering, 1320 Kinnear Road, Columbus, Ohio. Research was conducted under Contract F 19628-67-C-0308. Lt. Nyman was the Electronic Systems Division Program Monitor for this research. This report covers the period from 1 October to 30 December 1967.

This technical report has been reviewed and approved 9 February 1968.

BERNARD J. FILLIATREAULT
Contracting Officer
Space Defense System Program Office

ABSTRACT

This report outlines the progress in the past quarter in developing a computer program for direct scattering calculations.

TABLE OF CONTENTS

I. GOALS

Our purpose is to develop new theoretical and computational techniques for electromagnetic scattering. The end result will be a digital computer program designed to calculate the scattering properties of a wide class of targets.

II. PROGRESS WITH THE PHYSICAL OPTICS FORMULATION

A physical-optics scattering program was developed to read in the coordinates (x, y, z) of many points on the target surface and to calculate the projected area function, the CW scattering matrix, and the pulse response for the bistatic case. The program was tested for spheres with excellent results. Testing will proceed for targets of other shapes. The details of the physical-optics formulation are given in Report 2430-2.[2] Test results for the sphere are given in Appendix I.

III. PROGRESS WITH THE GEOMETRICAL THEORY OF DIFFRACTION

A computer program was developed for backscattering from perfectly conducting bodies of revolution. This program includes the scattering contributions from geometrical optics, creeping waves and wedge diffraction at the junctions of the analytic subsections of the target. The subroutines for the geometrical optics and creeping wave contributions were developed earlier in the contract period. In the past quarter, the wedge diffraction subroutine was developed and is now being tested.

A flow diagram of the wedge diffraction subroutine is shown in Fig. 1. Section 102 identifies the locations and included angles of any "wedges" on the target. (Here "wedge" is used to refer to a slope discontinuity at the junction of subsections of the target.) Section 103 identifies any planes, cones and cylinders that may exist as subsections of the target surface.

Next a loop is entered to increment the incidence angle and the wavelength. In this loop two tests are made in Sections 105 and 106. If the incident propagation axis is nearly parallel with the axis of the target, the wedge contributions are computed in Section 109 using Bessel functions. If the propagation axis is almost perpendicular to the surface of a plane, cone, or cylinder, the contribution is calculated

in Section 110 using the (sin X)/X function. The contributions from any remaining wedges are then computed and summed. Finally the elements of the scattering matrix are computed in Section 108.

This wedge diffraction subroutine is undergoing tests with cones, cylinders and cone-cylinders. The details of the formulation using the geometrical theory of diffraction are presented in Report 2430-1.[1]

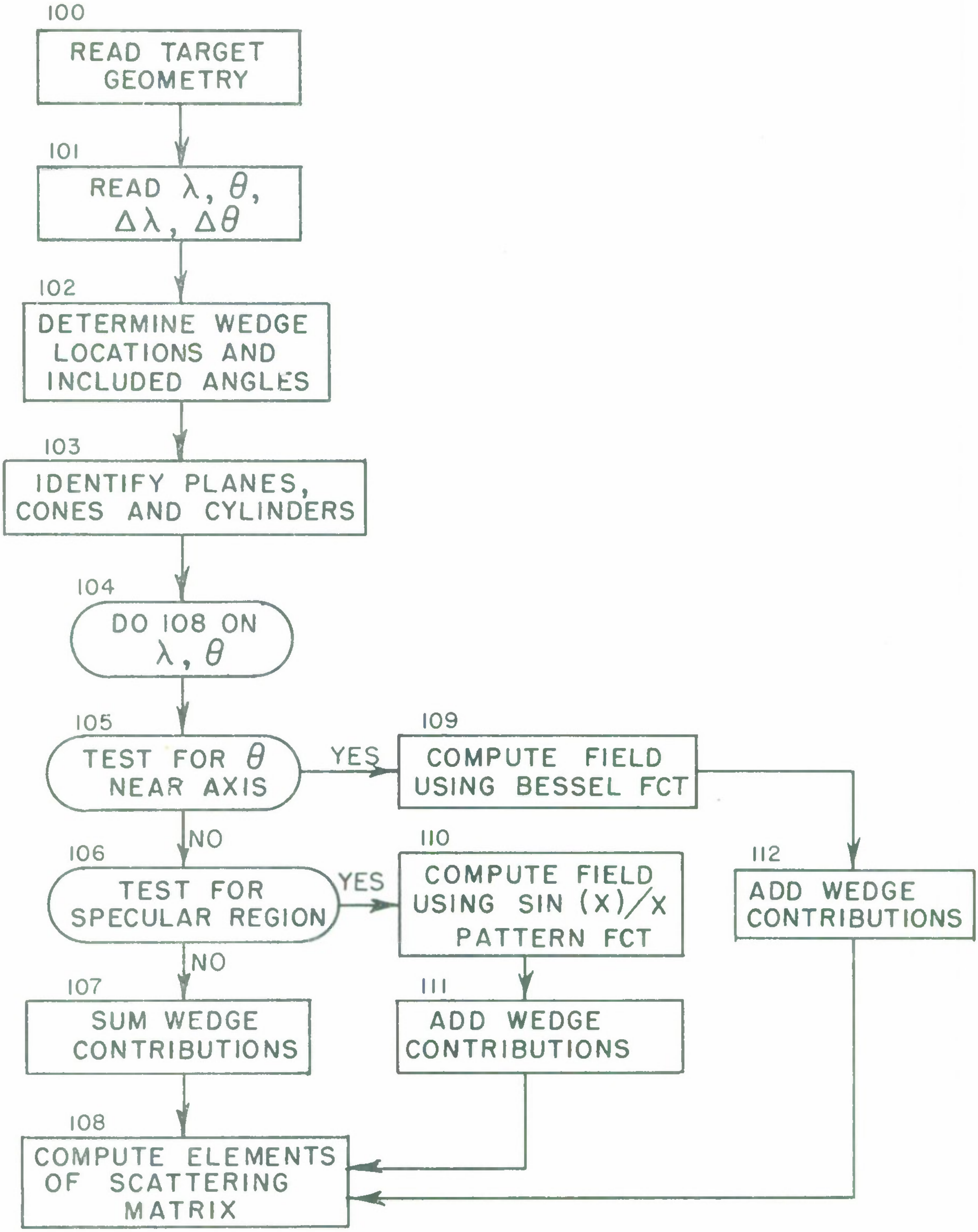

Fig. 1. Flow diagram for the wedge diffraction subroutine.

APPENDIX I
PHYSICAL OPTICS TEST RESULTS

The physical optics computer program has been tested with spherical and spheroidal targets with excellent results. The following targets are being considered for additional tests: ogive, cone, cylinder, combinations of the above shapes, and a tetrahedron.

The test results for the sphere are displayed in Figs. 2 through 5. In each figure, the dots represent the output data from the computer program. The input data for these computations included the coordinates (x, y, z) of 1083 points distributed almost uniformly over the surface of the sphere.

In Fig. 2 the computer output data shows good agreement with the physical optics data given by the solid curve. Better results could be obtained by including a larger number of points in the input data describing the target surface. The solid curve in Fig. 2 is based on the following expression for physical-optics backscatter from a sphere with radius "a".

$$\text{(1)} \qquad \sigma = \frac{\pi}{4k^2} \left| (j + 2ka)\, e^{j2ka} - j \right|^2$$

where $k = 2\pi/\lambda$.

Figure 3 shows backscatter results for the sphere as a function of the aspect angle. For a true sphere, the echo area is of course independent of aspect angle. Thus, the variations in the computer output data arise from the fact that the computer is programmed to approximate the spherical target with a polyhedron. Again, these variations could be reduced by specifying a larger number of points on the surface.

Figures 4 and 5 display the results for bistatic scattering from a sphere. The solid curves, shown for comparison, were obtained from the following expressions:

$$\text{(2)} \qquad S_x = ka^2 \int_0^{\pi/2} \sin^2\theta\, J_1(ka \sin\theta \sin\theta_s)\, e^{jka(1+\cos\theta_s)\cos\theta}\, d\theta$$

$$\text{(3)} \qquad S_y = 0$$

(4) $S_z = -jka^2 \int_0^{\pi/2} \sin\theta \cos\theta \, J_o(ka \sin\theta \sin\theta_s) \, e^{jka(1+\cos\theta_s)\cos\theta} \, d\theta$

(5) $S_{11} = -S_x \sin\theta_s - S_z \cos\theta_s$

(6) $S_{22} = -S_z$

(7) $\sigma_{11} = 4\pi |S_{11}|^2$

(8) $\sigma_{22} = 4\pi |S_{22}|^2$

where J_o and J_1 represent the Bessel functions. These equations represent the physical optics solution for the sphere under the conditions illustrated in Figs. 4 and 5, where $\theta_i = \phi_i = \phi_s = 0$.

The results shown in Figs. 2-5 demonstrate that the direct scattering computer program gives acceptable physical-optics data for spherical targets at frequencies up to 600 MHz when the input data includes at least 1000 points on the surface. This indicates that at least 20 points will probably be required for each square wavelength on any smooth target.

The short-pulse response has also been calculated for the sphere, with excellent results. These waveforms will be included in a future report.

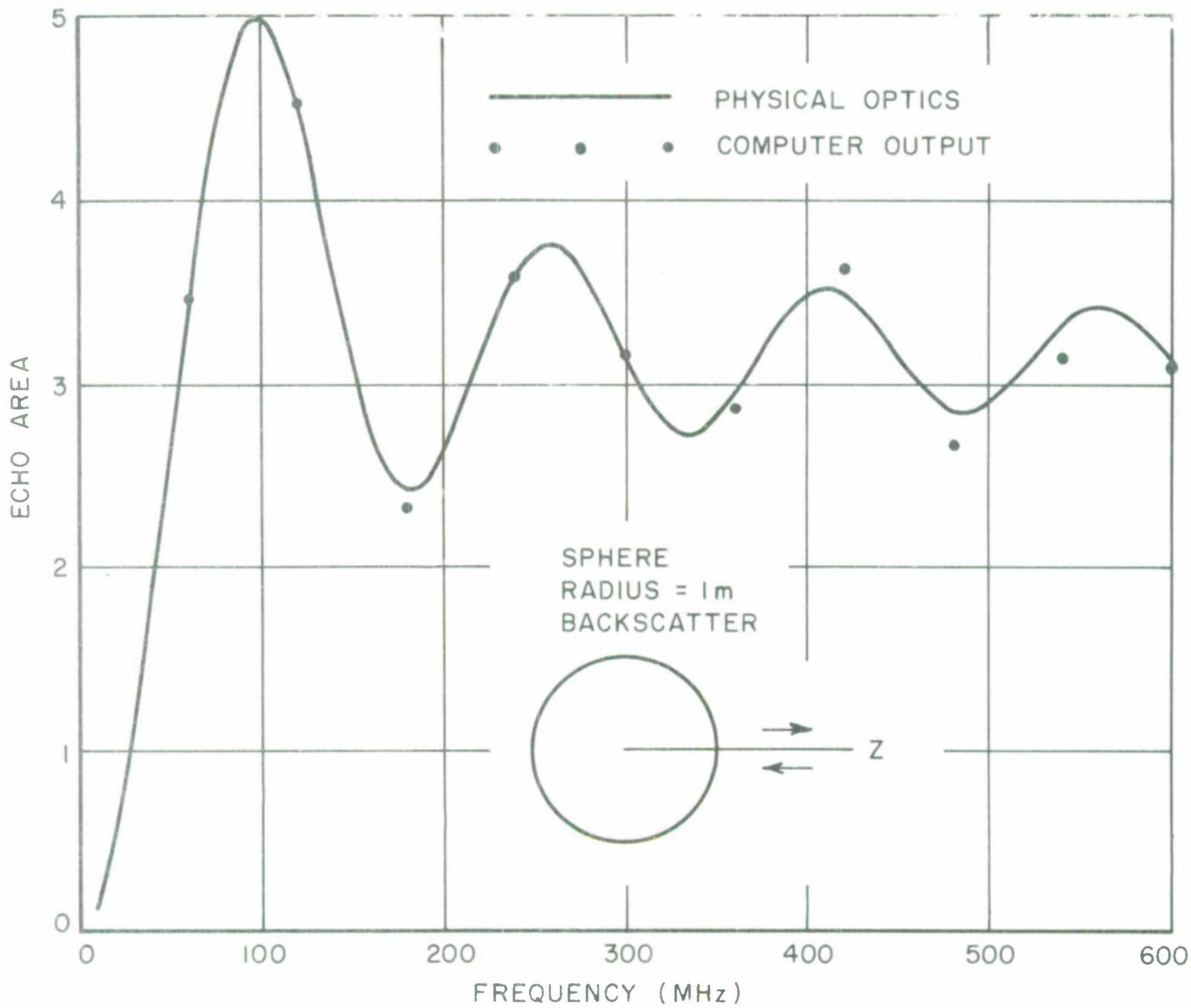

Fig. 2. Backscatter versus frequency for sphere.

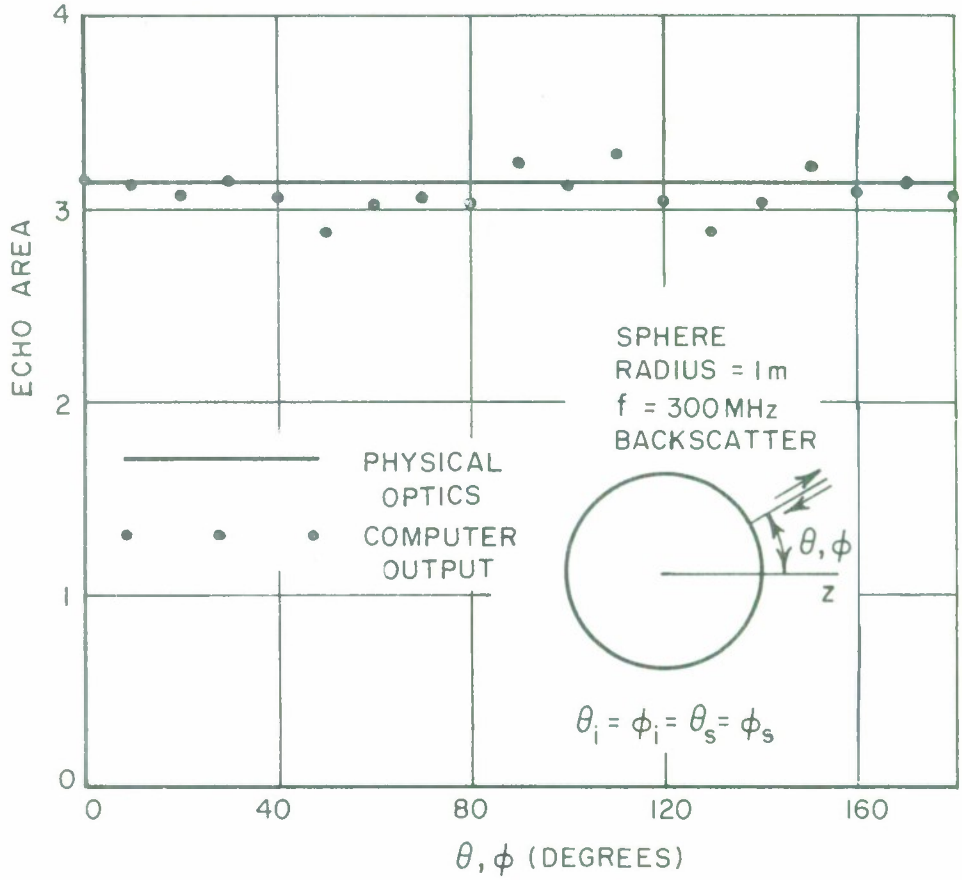

Fig. 3. Backscatter versus aspect for sphere.

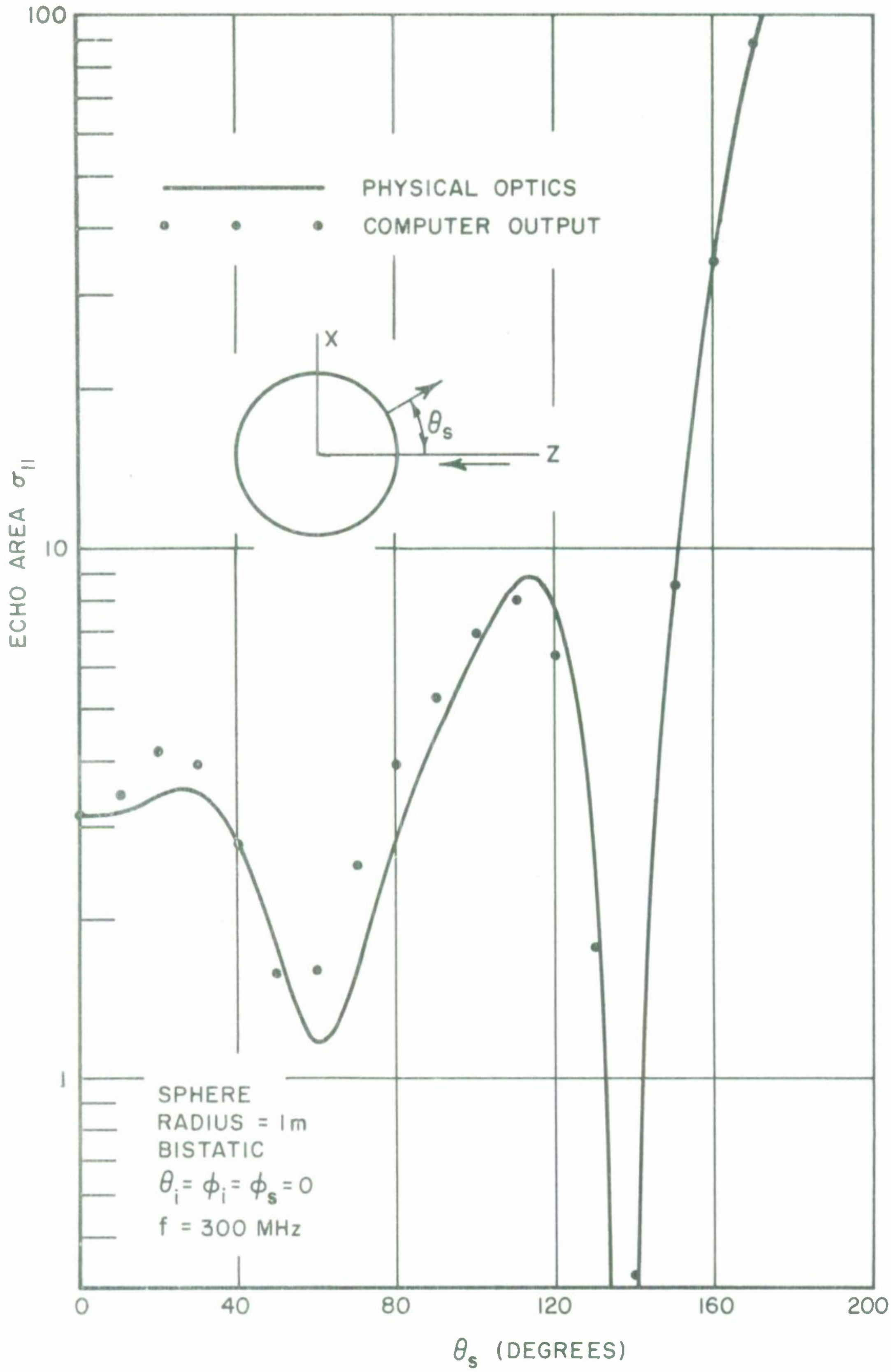

Fig. 4. Bistatic scattering from sphere (E plane).

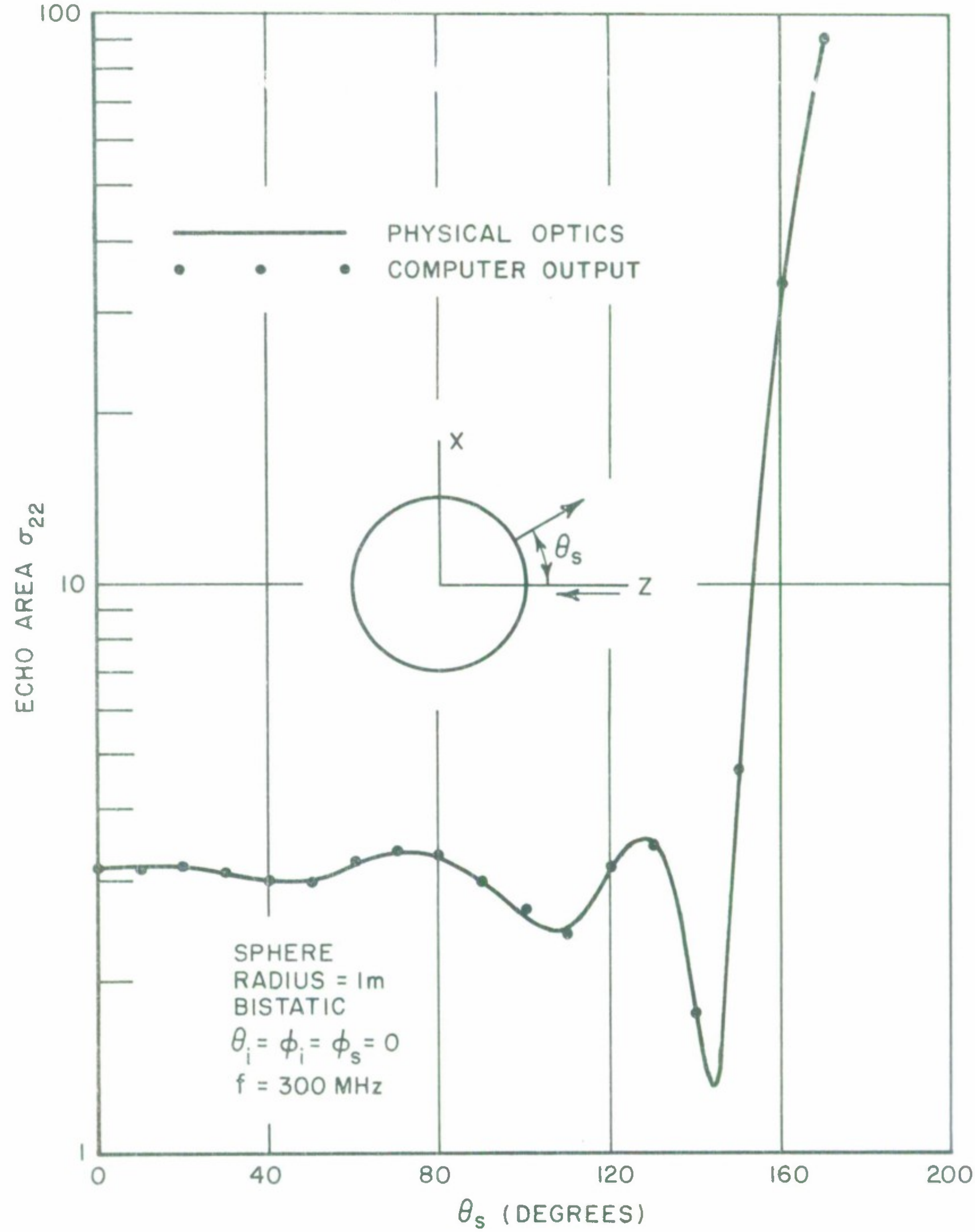

Fig. 5. Bistatic scattering from sphere (H plane).

REFERENCES

1. Ryan, C.E., Jr., "Memorandum Analysis of Echo Area of Targets Using Geometrical Theory of Diffraction and Creeping Wave Theory," Report 2430-1, July 1967, ElectroScience Laboratory, The Ohio State University Research Foundation; prepared under Contract F19628-67-C-0308 for Electronics Systems Division, Air Force Systems Command, Bedford, Massachusetts.

2. Second Quarterly Technical Report, 1 July to 30 September 1967, Report 2430-2, October 1967, ElectroScience Laboratory, The Ohio State University Research Foundation; prepared under Contract F19628-67-C-0308 for Electronics Systems Division, Air Force Systems Command, Bedford, Massachusetts.

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13. ABSTRACT

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